

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (currently amended): A network-independent, high-reliability communications system for an industrial controller using a standard serial communications network, the communications system comprising:
 - a first I/O communications circuit receiving I/O data for control of an industrial process;
 - a first network-independent protocol device receiving the I/O data and formatting it for transmission under a network-independent protocol to produce high-reliability formatted data formatted to reduce undetected transmission loop errors, the formatting including at least one of a cyclic redundancy code related to the I/O data and a sequence count related to the local order of transmission of the I/O data with respect to other I/O data being transmitted;
 - a first standard network protocol device receiving the high-reliability formatted data and further formatting it for transmission under a protocol of the standard serial communications network, to produce doubly-formatted data for transmission on the standard serial communications network, the protocol of the standard serial communications network also formatting data to reduce undetected transmission loop errors, the formatting including at least one of a cyclic redundancy code related to the I/O data and a sequence count related to the local order of transmission of the I/O data with respect to other I/O data being transmitted, the cyclic redundancy code and sequence count being redundant with the cyclic redundancy code and sequence count of the first network independent protocol device;
 - a second standard network-protocol device receiving the doubly-formatted data from the standard serial communications network and extracting the high-reliability formatted data according to the protocol of the standard serial communications network;
 - a second network-independent protocol device receiving the high-reliability formatted data and extracting the I/O data; and
 - a second I/O communications circuit receiving I/O data for control of an industrial process from the second network-independent protocol device;

whereby high-reliability transmissions may be simply obtained on an arbitrary standard serial communications network protocol.

2. (original) The industrial controller of claim 1 wherein the first and second I/O communications circuits are selected from the group consisting of an industrial controller, an input circuit for an industrial controller, a bridge, and an output circuit for an industrial controller.

3. (canceled)

4. (original) The industrial controller of claim 1 wherein the second network-independent protocol device further generates an acknowledgment message upon receipt of the I/O data and formats it under the network-independent protocol to produce a high-reliability formatted acknowledgment data;

and wherein the second standard network protocol device receives the high-reliability formatted acknowledgment data and further formats it for transmission under the protocol of the standard serial communications network, to produce doubly-formatted acknowledgment data for transmission on the standard serial communications network;

and wherein the first standard network-protocol device receiving the doubly-formatted acknowledgment data from the standard serial communications network and extracts the high-reliability formatted acknowledgment data according to the protocol of the standard serial communications network;

and wherein the first network-independent protocol device receiving the high-reliability formatted acknowledgment data checks the data to detect transmission loop errors.

5. (original) The industrial controller of claim 4 wherein the acknowledgment data includes the I/O data and the first network-independent protocol device detects errors by comparing the I/O data to the acknowledgment data.

6. (original) The industrial controller of claim 1 wherein the first network-independent protocol device operates to start a timer upon receipt of the I/O data and wherein the first network-independent protocol device detects errors by checking a time on the timer against an allowable time upon receipt of the acknowledgment message.

7. (original) The industrial controller of claim 1 wherein the first network-independent protocol device transmits I/O data on a regular interval and wherein the second network-independent protocol device detects errors by comparing the time at which the last I/O data was received against the time interval.

8. (original) The industrial controller of claim 1 wherein the second network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

9. (original) The industrial controller of claim 4 wherein the first network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

10. (original) The industrial controller of claim 1 wherein the standard serial communications network is selected from the group of networks consisting of Ethernet, DeviceNet, ControlNet, Fire Wire and Field Bus.

11. (currently amended) A method of providing a high-reliability communications system for an industrial controller using a standard serial communications network, the communications system comprising the steps of:

(a) receiving I/O data for control of an industrial process at a first I/O communications circuit;

(b) formatting the received I/O data for transmission under a network-independent protocol at a first standard network protocol device to produce high-reliability formatted data formatted to reduce undetected transmission loop errors, the formatting including at least one of a cyclic redundancy code related to the I/O data and a sequence count related to the local order of transmission of the I/O data with respect to other I/O data being transmitted;

(c) receiving the high-reliability formatted data at a first standard network protocol device and further formatting it for transmission under a protocol of the standard serial communications network, to produce doubly-formatted data for transmission on the standard

serial communications network, the protocol of the standard serial communications network also formatting data to reduce transmission loop errors, the formatting including at least one of a cyclic redundancy code related to the I/O data and a sequence count related to the local order of transmission of the I/O data with respect to other I/O data being transmitted, the cyclic redundancy code and sequence count being redundant with the cyclic redundancy code and sequence count of the first network independent protocol device;

(d) receiving the doubly-formatted data from the standard serial communications network at a second standard network-protocol device and extracting the high-reliability formatted data according to the protocol of the standard serial communications network;

(e) receiving the high-reliability formatted data at a second network-independent protocol device and extracting the I/O data; and

(f) receiving I/O data for control of an industrial process from the second network-independent protocol device at a second I/O communications circuit;

whereby high-reliability transmissions may be simply obtained on an arbitrary standard serial communications network protocol.

12. (canceled)

13. (original) The method of claim 11 including the further steps of:

(e) generating a reply message by the second network-independent protocol device upon receipt of the I/O data formatted under the network-independent protocol to produce a high-reliability formatted acknowledgment data;

(f) receiving the high-reliability formatted acknowledgment data at the second standard network protocol device and further formatting it for transmission under the protocol of the standard serial communications network, to produce doubly-formatted acknowledgment data for transmission on the standard serial communications network;

(g) receiving the doubly-formatted acknowledgment data from the standard serial communications network at the first standard network-protocol device and extracting the high-reliability formatted acknowledgment data according to the protocol of the standard serial communications network; and

(h) receiving the high-reliability formatted acknowledgment data at the first network-independent protocol device to detect transmission loop errors.

14. (original) The method of claim 13 wherein the acknowledgment data reflects the I/O data and wherein at step (h) the first network-independent protocol device detects errors by comparing the I/O data to the acknowledgment data.

15. (original) The method of claim 11 wherein at step (b) the first network-independent protocol device starts a timer upon receipt of the I/O data and wherein at step (h) the first network-independent protocol device detects errors by checking a time on the timer upon receipt of the acknowledgment message.

16. (original) The method of claim 11 wherein at step (b) the first network-independent protocol device transmits I/O data on a regular interval and wherein at step (e) the second network-independent protocol device detects errors by comparing the time at which the last I/O data was received against the time interval.

17. (original) The method of claim 11 wherein at step (e) the second network-independent protocol device uses the formatting of the first network-independent protocol device to detect transmission loop error in transmission of the I/O data, and upon the detection of an error for I/O data to assume a default safety state of the I/O data.

18. (original) The method of claim 13 wherein the first network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

19. (original) The method of claim 11 wherein the standard serial communications network is selected from the group of networks consisting of Ethernet, DeviceNet, ControlNet, Fire Wire and Field Bus.